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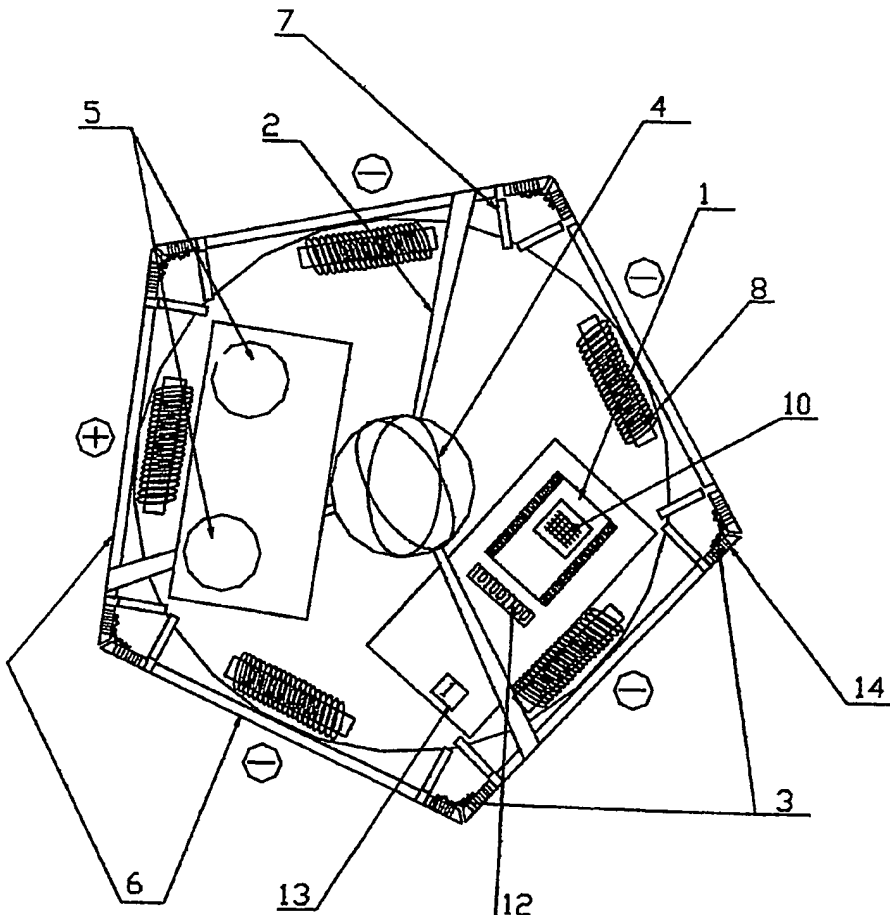
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(54) Title: A SYSTEM OF THREE-DIMENSIONAL MULTIPURPOSE ELEMENTS



(57) Abstract: A system of three-dimensional multipurpose elements consists of single solid elements, which can be computer-controlled to move, connect one to and disconnect one from another. A single element of the system consists of a casing made up of walls (6), linked with each other by means of electroplastic actuator (3) which change the reciprocal position of the walls of the casing of a single element. Changes in the reciprocal position of the walls occur according to the exciting signal transmitted from a programmable integrated circuit (1). Heat emitters (14) carry away excess heat from the system devices. Inside a single element there are provided interlocks (7) for connecting respective single elements, as well as magnetic coils (8) and a voltage source (5) supplying the integrated circuit (1), interlocks, magnetic coils and electroplastic actuator.

WO 2004/062759 A1



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## A System of Three-Dimensional Multipurpose Elements

### 5 Technical Field

The subject of the invention is a system of three – dimensional multipurpose elements used for creating three-dimensional constructions, having a vast range of forms, colours and materials, mechanical, kinematics and functional properties, by making use of autonomously independent solid elements.

- 10 According to the invention, the system of three-dimensional multipurpose elements may be applied, through making functional copies of the original, in various technologies, for example in space technologies, furniture industry, decorative and building industry, toy-making and entertainment industry, orthopaedics, three-dimensional mobile telephony, for manufacturing
- 15 industrial, rescue and household robots, and finally, for generating research simulation systems, especially in genetics, crystallography and chemistry.

### Background Art

- The description of International patent application PCT/GB95/00460 (publication no WO 95/23676) reveals some programmable materials
- 20 constituting a set of hexagonal bricks, named monomers, which can move towards each other in a computer-controlled mode and create structures and mechanisms. Monomers can both combine with other monomers and move towards each other unseparated. In case a monomer is damaged, those still in existence eliminate it and replace with a good clone. The motion of
- 25 monomers is systematically split into streams, gates, trunk lines and containers for designating individual paths of motion of respective monomers necessary in the synthesis of the entire structure. Specialised monomers are provided with tools, which form the intended devices together with the intended and synthesised structure. Monomers have grooves in the vertical
- 30 symmetry axes of the sidewalls; instead, inside monomers there are protrusive interlocks provided with sliding wedges. Neighbouring monomers may be combined and blocked with each other or linked in such a way that their reciprocal translocations upon connecting are possible through a

toothed bar and a toothed wheel [s] or otherwise. Respective monomers maybe positioned with each other through a system of latches controlled either with an electromagnet or a linear induction motor. The second monomer form is provided with four symmetrical grooves on each wall, the grooves being positioned at an angle of  $45^{\circ}$  to the wall symmetry axis. Those grooves serve for inserting elements, which block the mutual connection of neighbouring monomers. The third monomer form is provided with frontal elements on all six walls, the elements being supplied with tee section grooves placed in the symmetry axes of the elements. In the grooves are placed latch units, which allow aligning the reciprocal position of the monomers being linked. The latch units are controlled by gear transmissions arranged vertically to the external surface of the frontal elements of monomer. Linear induction motors with electromagnets secure the transport of monomers. The linear induction motors of stationary monomers translate the monomers, which are to be transported. A precise co-ordination of linear induction motors of the series of stationary monomers allows attaining a high transport velocity along that series. Electricity is supplied and the transmission of the controlling data occurs from the central source through neighbouring monomers. The paper entitled „3-D Self-Assembling and Actuation of Electrostatic Microstructures” published in the „IEEE TRANSACTION ON ELECTRON DEVICES” VOL. 48, NO 8, AUGUST 2001 reveals a three - dimensional self-assembling and starting electrostatic microstructure. The purpose of the microstructure is completion of the dedicated controlling elements for optical applications, and especially, for micro-mirror matrices with large angels of reflection. The initial flat structure is performed inside one polysilicon structural layer. The mobile structure contains a rotating plate connected with two principal supporting beams through thin elastic props. Combinations of four integrated final control units SDA determine the supporting beams. Through a pulsating electric signal, SDA elements move and eventually bend the initially flat structural layer. Reached the required shape of the structure, the respective elements are mechanically blocked.

In addition, the publication „Self-Assembling Machine” (PROCEEDINGS OF THE INTERNATIONAL CONFERENCE ON ROBOTICS AND

- AUTOMATION, San Diego, MAY 8 – 13, 1994, LOS ALAMITOS, IEEE COMP. SOC. PRESS, US) reveals a self-assembling device consisting of identical elements completing a two-dimension machine. Each element is made up of three layers and has no mobile parts. The top and bottom layers have identical shapes and each contains three magnets arranged symmetrically, while their magnetic north pole is placed on the bottom layer. The middle layer has the same shape as the top and bottom ones, but is turned at an angle of  $60^{\circ}$  towards them and contains three electromagnets in lieu of magnets.
- 10 The electromagnets have the magnets retracted or pushed out according to the polarisation of the voltage applied and may rotate between two magnets without any effect on the magnetic field. Each element may be linked to no more than other 6 elements. The communication between respective elements is secured due to an infrared optical system. The relays and
- 15 receivers are arranged in the holes in the middle of the magnets and electromagnets. In the communication is applied an asynchronous series protocol. An 8-bit processor is to decide on the polarisation of the electromagnets in compliance with the information received. Electricity is provided in a wireless system where the plate on which the elements are
- 20 arranged is used as supply terminal. The plate is divided into zones and every second of them is connected to the supply voltage, whereas the remaining ones are earthed. The elements are fed from four contacts and a rectifier. Respective elements have only information on local connections with the neighbouring elements. The shape of the entire structure is
- 25 described basing upon local links between respective elements.

#### Disclosure of Invention

- According to the invention, in the system of three-dimensional multipurpose elements, consisting of single solid elements, which can translocate, connect one to and disconnect one from another, containing programmable integrated
- 30 circuits, interlocks for linking respective single elements and electromagnets, the casing walls of a single element of the system have magnetic polarisation depending on the programmed position of the single element in the real structure under formation. In the active state of a single element, the walls of

the casing of a single element of the system have different magnetic polarisation, whereas in the inactive state of a single element, the walls of the casing of a single element of the system have identical magnetic polarisation. Upon connecting an active single element of the system to an inactive single element of the system, information about a virtual object and information about the successive running number in the real structure of the inactive single element of the system being connected is transmitted from an active single element of the system to the memory of the integrated circuit of the inactive single element of the system. Sets of co-ordinates of the walls of the casing of a given single element of the system are assigned to the running numbers of single elements of the system. The sets of those data are transferred to the program in the integrated circuit of each single element of the system, while the program in the integrated circuit is to decide on both activation or deactivation of the respective walls of single elements of the system and assigning a proper running number to a single element of the system to be linked successively.

Magnetic polarisation in the walls of the casing of a single element of the system is generated by electromagnets placed inside a single element of the system. The walls of the casing of a single element of the system are connected to each other so that their reciprocal position can be changed. The walls of the casing of a single element of the system are connected with each other by means of electroplastic actuators, which control the reciprocal positioning of the walls according to the exciting signals transmitted from the programmable integrated circuit.

A single element of the system has a voltage source supplying the integrated circuit, interlocks, electromagnets and electroplastic actuators.

The voltage source is renewable due to supply from solar batteries. The light to the solar batteries is carried in light pipes which also carry both information on the object and program instructions to the integrated circuit. The real structure of the object may be dissipated to the initial state of single elements of the system through deactivation of all casing walls of single system elements and disconnection of all interlocks in consequence of transmitting information to the integrated circuit.

According to the invention, the system enables a multiple use of the same single elements of the system for making new structures having destroyed first the previous structure. Each of the single elements of the system has got a set of information necessary for reconstructing a real structure designed.

- 5 From any quantity of single elements of the system one can create structures and constructions, designed according to one's wish, and having a vast range of forms, colours and materials, mechanical, kinematics, material and dynamic properties.

#### Brief Description of Drawings

- 10 The system of three-dimensional multipurpose elements and its function is explained in detail taking as example its version as in Fig. 1 presents an outlined structure of an active element of the system, Fig. 2 – an outlined structure of an inactive single element of the system, Fig. 3 – The initial phase of connection under execution of a single active element of the system
- 15 with an inactive element of the system, Fig. 4 – the final phase of connection of an active single element of the system with an inactive single element of the system, Fig. 5 – an outlined permanent connection of five single elements of the system making the real structure, Fig. 6 – a picture of a real, three-dimensional structure made up of five single elements of the system, and
- 20 finally, Fig. 7 shows a simplified view of a mobile container with single elements of the system placed in it.

#### Best Mode for Carrying Out the Invention

- A single element of the system of three-dimensional multipurpose elements consists of a casing made up of walls 6 linked to each other by means of
- 25 electroplastic actuators 3 which can change the reciprocal position of the walls 6 of the casing of a single element of the system of three-dimensional multipurpose elements through tensioning or slackening. Changes in the reciprocal position of the walls 6 occur according to the exciting signal transmitted from a programmable integrated circuit 1. Heat emitters 14 carry
- 30 away both excess heat generated in the process of changes of reciprocal position of the walls 6 of the casing of a single element and the heat from other system devices. Inside a single element there are provided interlocks 7

decide on both activation or deactivation of the respective walls 6 of single elements of the system and assigning a proper running number 13 to a single element of the system to be linked successively. When the successive single element of the system is linked to the prior single element of the system the connection is blocked by means of interlocks 7 of any type. The procedure of linking and activating respective single elements of the system and making the real structure of the object 9 remains in course until all single elements of the system, within the range of all running numbers 13, available in the virtual object 10 in the integrated circuit 1 are connected. Completed all connections between single elements of the system, there appears the real structure 9 complying with the virtual object 10. The real structure 9 of the object can be dissipated to the initial state of the single elements of the system, viz. to a loose initial set of inactive single elements of the system. This occurs through deactivation of all walls 6 of the casings of single elements of the system and disconnection of all interlocks 7 in consequence of having transferred appropriate information to all integrated circuits 1 of the real structure 9. After such a deactivation, all single elements of the system of three-dimensional multipurpose elements may be re-used for making a new three-dimensional structure for any purpose desired.



for connecting respective single elements, magnetic coils 8 and a voltage DC source 5 supplying the integrated circuit 1, interlocks 7, magnetic coils 8 and electroplastic actuators 3.

The voltage source 5 is renewable due to supply from solar batteries 4. The  
5 light to the solar batteries is carried in light pipes 2, which also carry both informations on the object 10 and program instructions 12 to the integrated circuit 1.

In the inactive state, the single element of the system of three-dimensional multipurpose elements has all walls 6 of the casing polarised with identical  
10 [negative or positive] magnetic poles. In the active state, the respective walls 6 of the casing of a single element may be polarised with different magnetic poles. Polarisation on the respective walls 6 of the casing of a single element of the system depends on the position of the given element of the system in the real structure under creation 9 according to the virtual structure of the  
15 object 10 programmed in the integrated circuit 1. The set of inactive single elements of identical magnetic polarity, placed in the container 11 [Fig 7], is subject to a constant motion under control. As soon as an active single element of the system has appeared in the set of single inactive elements of the system, the nearest inactive element of the system is connected to the  
20 active element of the system. The first active single element of the system has the initial number 13 of the virtual structure of the object 10, marked 1, and corresponds to the same number in the real structure 9 under creation (Fig.6).

Upon connecting an active single element of the system to an inactive single  
25 element of the system, both an information on a virtual object 10 and an information on the successive running number 13 in the real structure 9 of the inactive single element of the system being connected is transmitted from an active single element of the system to the memory of the integrated circuit 1 of the inactive single element of the system, while sets of co-ordinates of  
30 the walls 6 of the casing of a given single element of the system are assigned to the running numbers 13 of single elements of the system, the sets of those data are transferred to the program 12 in the integrated circuit 1 of each single element of the system. According to the data transmitted regarding the virtual object 10, the program 12 in the integrated circuit 1 is to

## Claims

1. A system of three-dimensional multipurpose elements, consisting of single solid elements, which can move, connect one to and disconnect one from another, containing programmable integrated circuits, interlocks for linking respective single elements and electromagnets; of the system said being characteristic that the casing walls (6) of a single element of the system have magnetic polarisation depending on the programmed position of the single element in the real structure under formation (9), and at the same time, in the active state of a single element, the walls (6) of the casing of a single element of the system have different magnetic polarisation, whereas in the inactive state of a single element, the walls (6) of the casing of a single element of the system have identical magnetic polarization, and upon connecting an active single element of the system to an inactive single element of the system, information about a virtual object (10) and information on the successive running number (13) in the real structure (9) of the inactive single element of the system being connected is transmitted from an active single element of the system to the memory of the integrated circuit (1) of the inactive single element of the system, while sets of co-ordinates of the walls (6) of the casing of a given single element of the system are assigned to the running numbers (13) of single elements of the system, the sets of those data are transferred to the program (12) in the integrated circuit (1) of each single element of the system, and the program (12) in the integrated circuit (1) is to decide on activation or deactivation of the respective walls (6) of single elements of the system and on assigning a proper running number (13) to a single element of the system to be linked successively.
2. A system according to Claim 1, characteristic thereof being that magnetic polarization in the walls (6) of the casing of a single element of the system is generated by electromagnets (8) placed inside a single element of the system.

3. A system according to Claim 1, characteristic thereof being that the walls  
(6) of the casing of a single element of the system are connected to each  
other so that their reciprocal position can be changed.
4. A system according to Claim 3, characteristic thereof being that the walls  
5 (6) of the casing of a single element of the system are connected with  
each other by means of electroplastic actuator (3) which control the  
reciprocal positioning of the walls (6) according to the exciting signals  
transmitted from the programmable integrated circuit (1).
5. A system according to Claim 1, characteristic thereof being that a single  
10 element of the system has a voltage source (5) supplying the integrated  
circuit (1), interlocks (7), electromagnets (8) and electroplastic actuator  
(3).
6. A system according to Claim 5, characteristic thereof being that the  
voltage source (5) is renewable due to supply from solar batteries. (4).
- 15 7. A system according to Claim. 6, characteristic thereof being that the light  
to the solar batteries (4) is carried in light pipes (2).
8. A system according to Claim 1 or 7, characteristic thereof being that the  
light pipes (2) carry to the integrated circuit (1) both information on the  
object (10) and program instructions (12)
- 20 9. A system according to Claim 3, characteristic thereof being that to running  
numbers (13) are assigned sets of co-ordinates of the walls (6) of single  
elements of the system, whereas the sets of those data are transferred to  
the program (12) in the integrated circuit (1) of each single element of the  
system.
- 25 10. A system according to Claim 1, characteristic thereof being that the real  
structure (9) of the object may be dissipated to the initial state of single  
elements of the system through deactivation of all casing walls (6) of  
single system elements and disconnection of all interlocks (7) in  
consequence of having transmitted appropriate information to the  
30 integrated circuit (1).

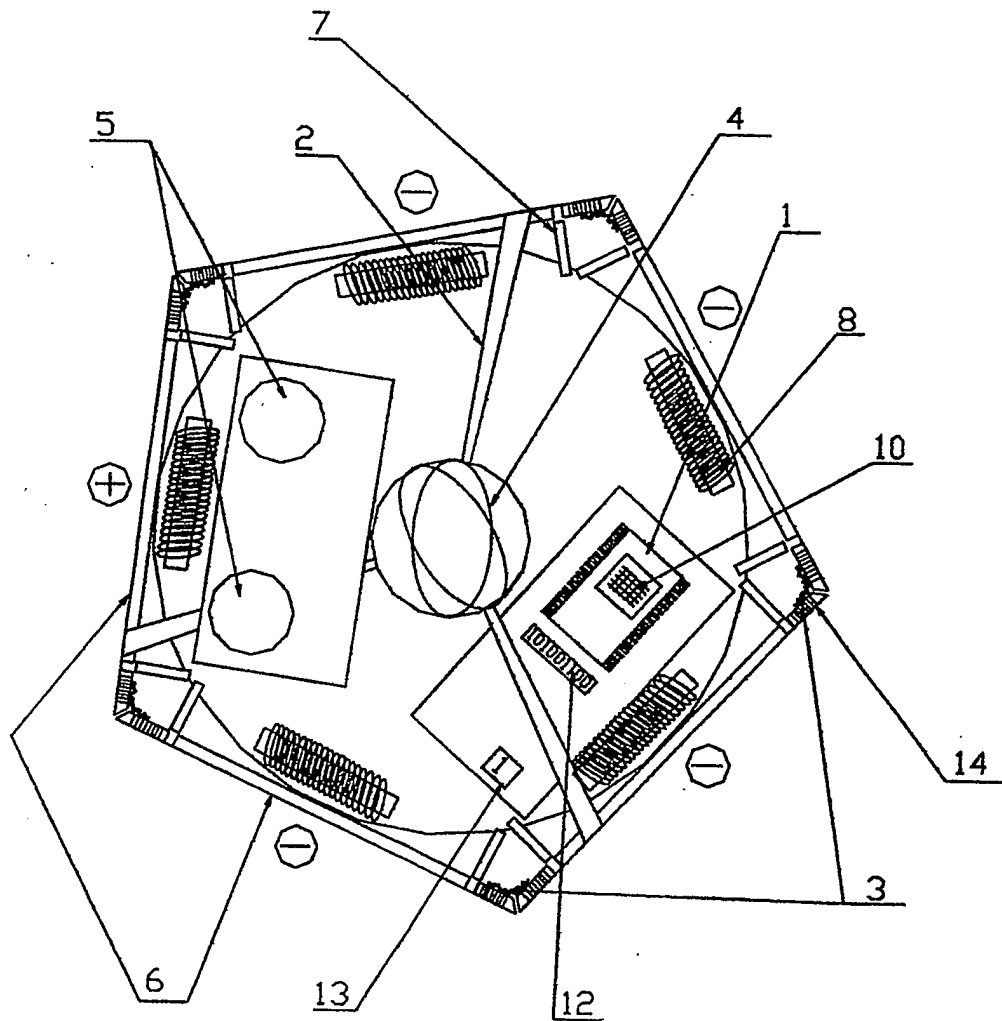


Fig. 1

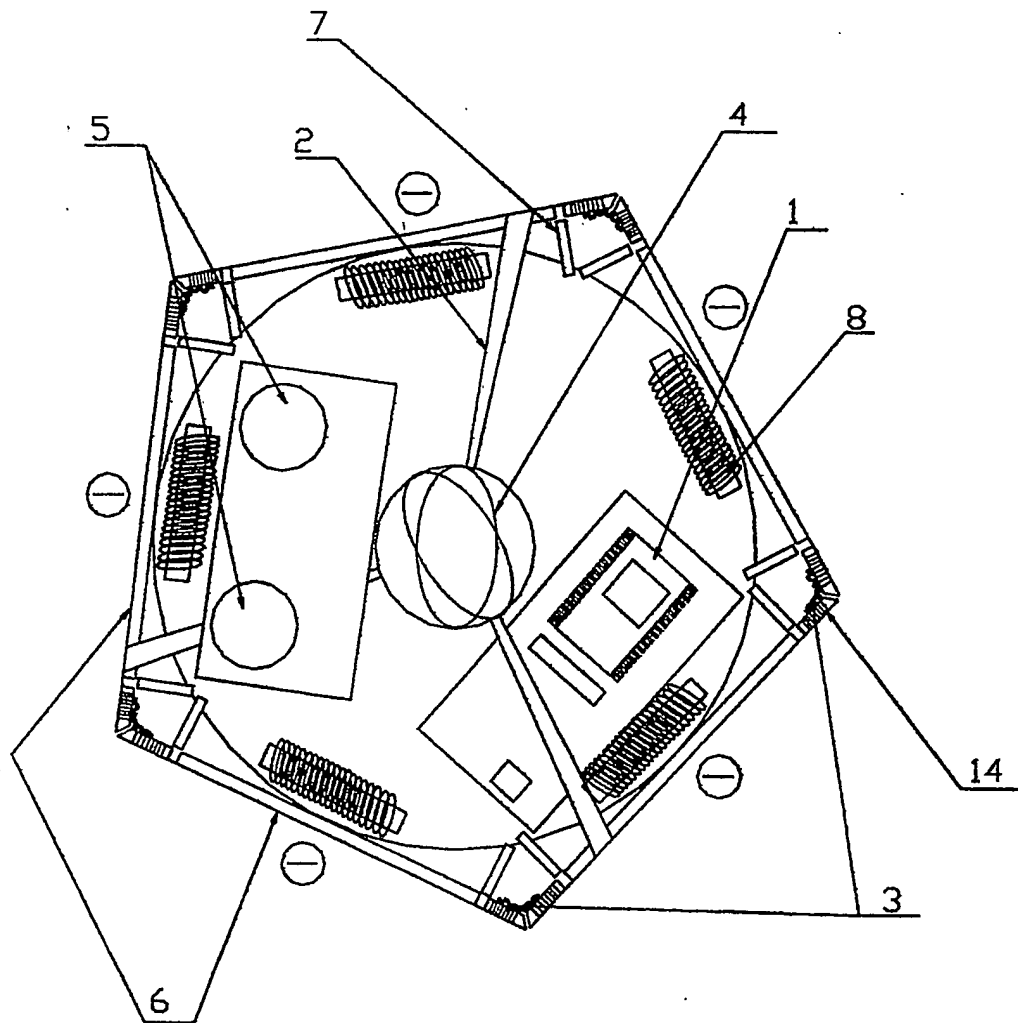


Fig. 2

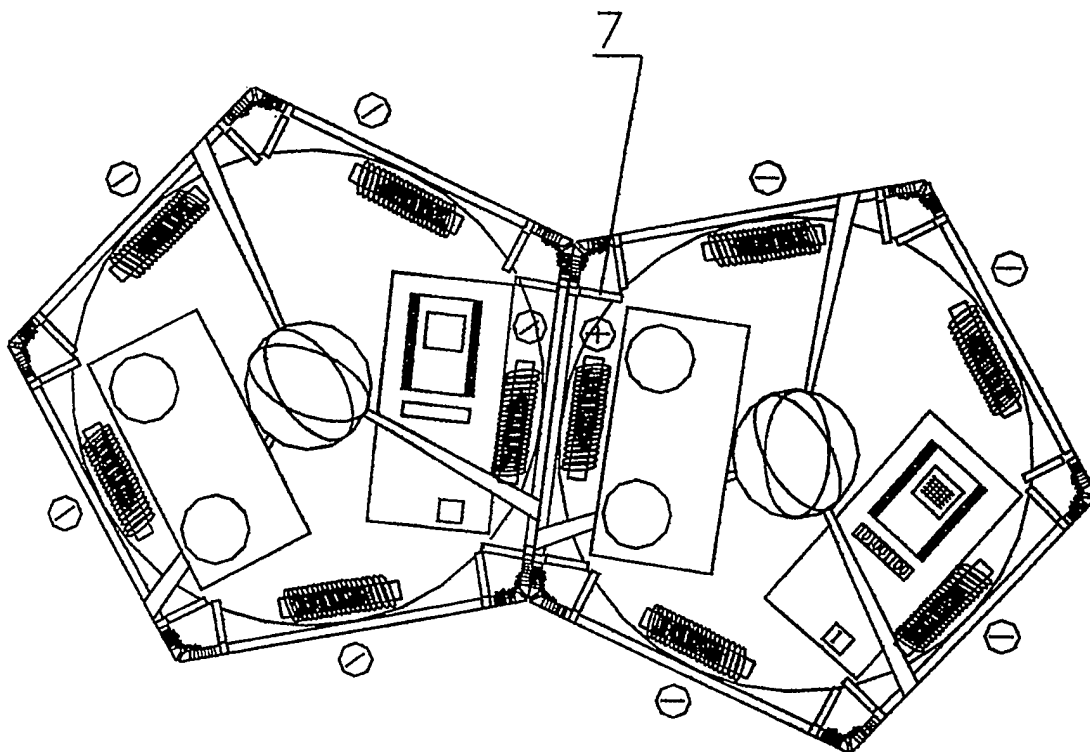


Fig. 3

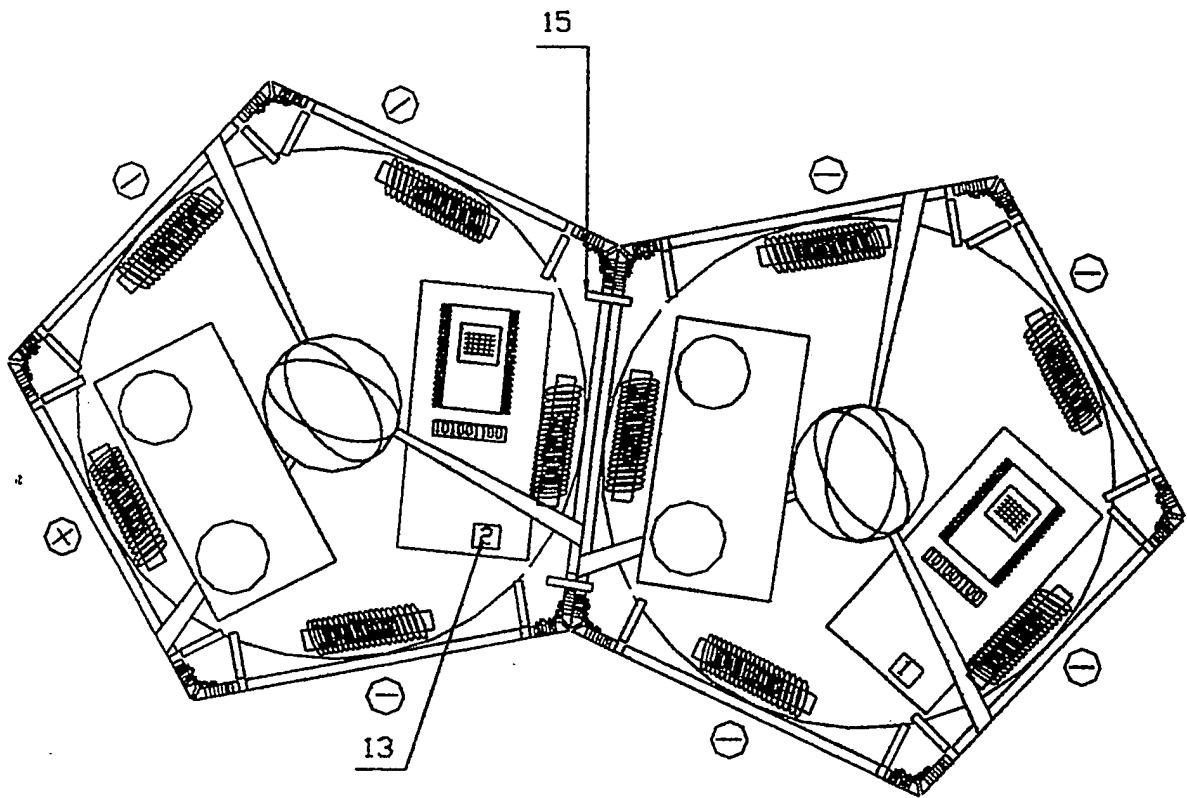


Fig. 4

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5/7

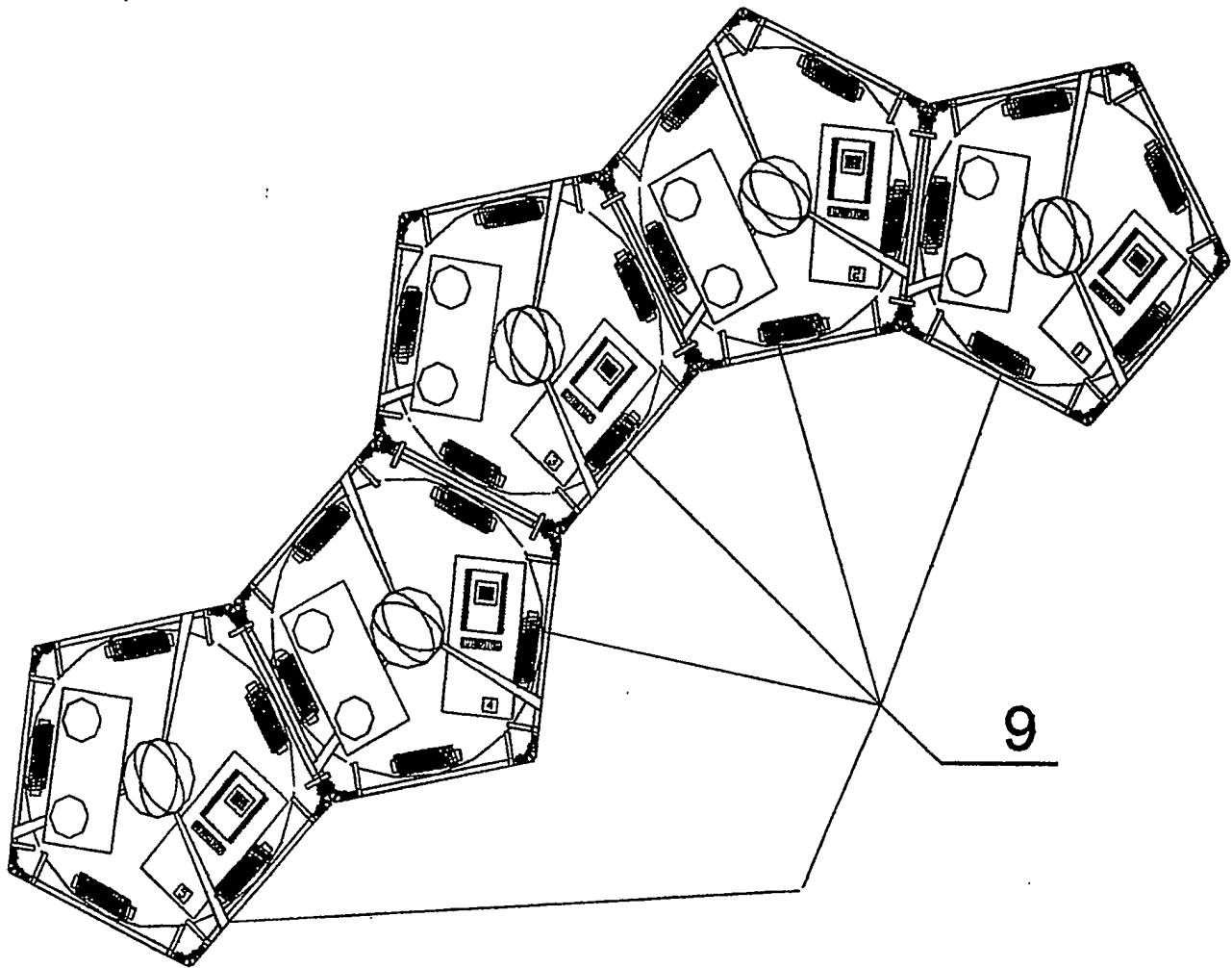


Fig. 5



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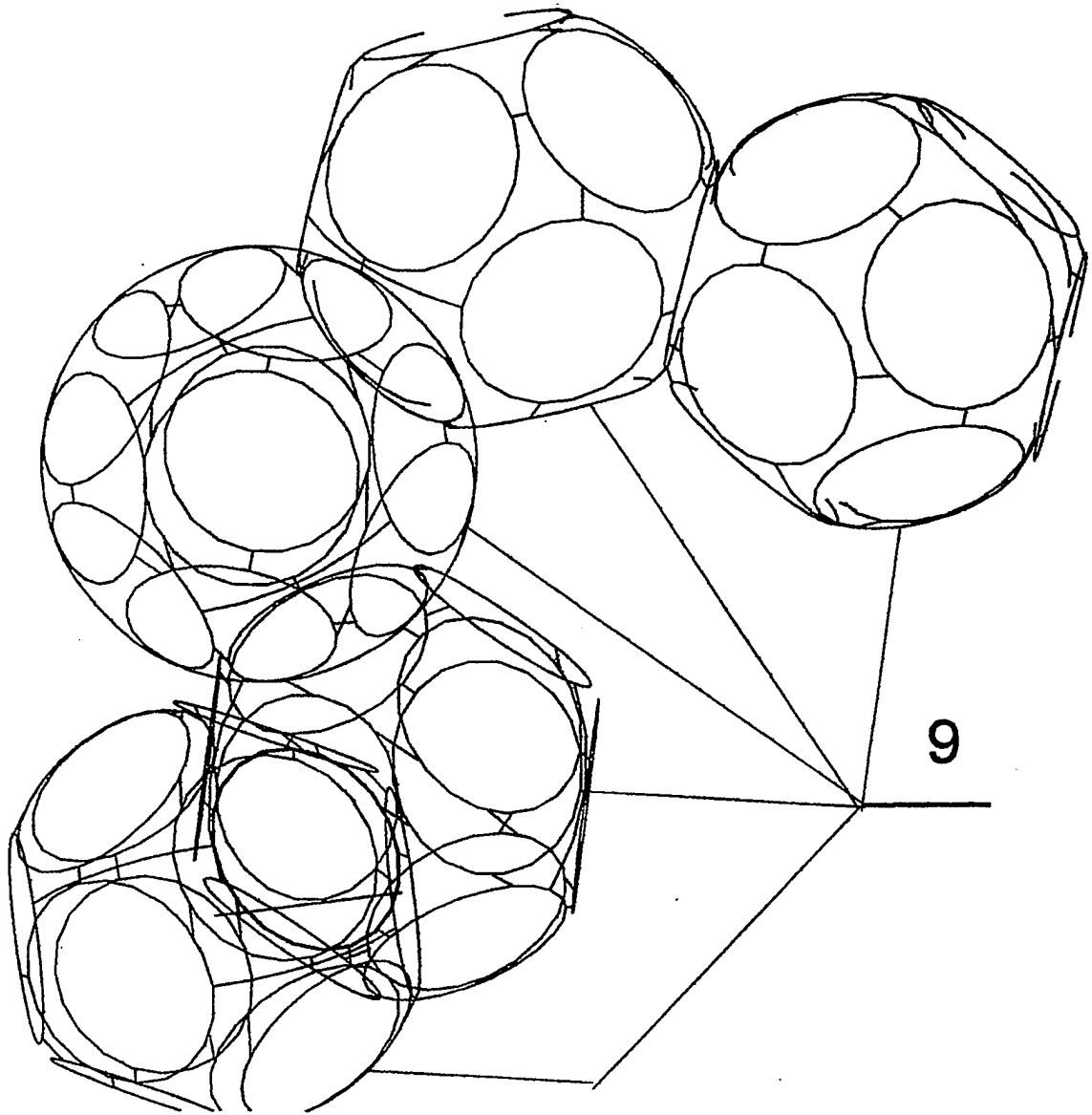


Fig. 6

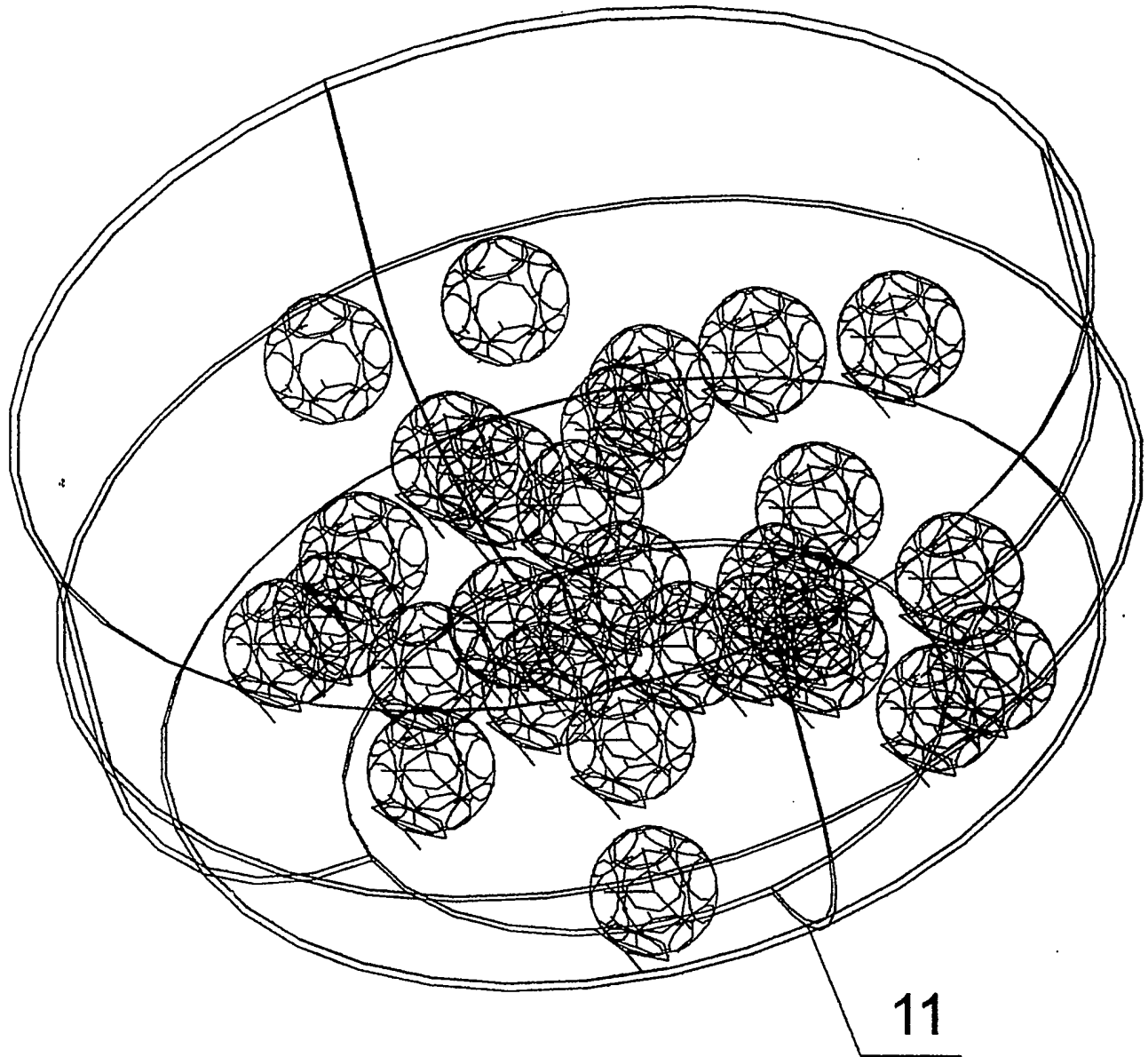


Fig. 7

*Article 19*

Amended claims

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1. The system of three-dimensional multipurpose elements consisting of single solid elements which can move, connect one to and disconnect one from another, containing programmable integrated circuits, interlocks and electromagnets, characterised by that every single element of the system has casing walls (6) having variable magnetic polarisation, the element has a voltage source (5) inside, and every single element of the system contains programme instructions.
2. The system according to claim 1, characterised by that the casing walls (6) are connected to each other so that their reciprocal position can be changed.
3. The system according to claim 1, characterised by that the casing walls (6) are connected to each other by means of electroplastic actuator (3) which is connected to the programmable integrated circuit (1).
4. The system according to claim 1, characterised by that the voltage source (5) is a renewable source.
5. The system according to claim 4, characterised by that the renewable voltage source (5) is renewable due to supply from solar batteries (4).
6. The system according to claim 5, characterised by that the light to the solar batteries (4) is carried in light pipes (2).
7. The method for creating three-dimensional constructions consisting in connecting and disconnecting of three – dimensional multipurpose elements as a result of their reciprocal positions characterised by that the reciprocal position of single multipurpose elements is the result of change of electromagnetic polarisation of their casing walls (6), and the change is realised by activation or inactivation single elements of the system, and the information about a virtual object and about the successive running number of the real structure of the inactive single element being connected are transmitted from an active single element of the system to the memory of the integrated circuit (1) of the inactive single element of the system, and the integrated circuit (1) decides on activation or deactivation of the respective walls (6) of the single elements of the system to be linked successively.